Loss-Reduction Provisions of A Federal Earthquake Insurance Program

Final Report

Issued in Furtherance of the Decade
for Natural Disaster Reduction

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LOSS-REDUCTION PROVISIONS OF A FEDERAL EARTHQUAKE INSURANCE PROGRAM

Final Report

Prepared for

The Federal Emergency Management Agency (FEMA)

Under
Contract No. EMW-88-C-2872

by

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EXECUTIVE SUMMARY

In anticipation of current proposed legislation concerning federal earthquake insurance or reinsurance, this report on the loss-reduction component of federal earthquake insurance programs was prepared by Dames & Moore under contract to the Federal Emergency Management Agency (FEMA) (No. EMW-88-C-2872). Significant assistance on this project was provided by the University of Southern California, University of Pennsylvania, George Washington University, Milliman & Robertson, Inc., and Risk Engineering, Inc.

Procedures utilized to conduct the study include a thorough examination of existing information on available earthquake hazard reduction activities and techniques, three meetings of a nationally recognized advisory panel, and a project workshop. The project workshop involved experts and representatives of many diverse agencies, organizations, and interests from throughout the country in order to construct acceptable findings. A nationally recognized Advisory Panel provided critical review of project progress and findings.

Major project findings include the following:

(1) There are cost-effective, technically credible earthquake loss-reduction measures (LRMs), chiefly in landuse and building practice, that are acceptable for inclusion in a federal earthquake insurance or reinsurance program. Table 1 summarizes those acceptable LRMs identified in this project. Figure 1 provides a small-scale seismic zonation map that suggests where the LRMs in Table 1 can be applied to zones of seismic hazard (numbered 0 through 4) throughout the United States.

(2) Current earthquake risk analysis techniques -- in spite of their uncertainties -- are acceptable for the evaluation of LRMs and the determination of both primary earthquake insurance rates and secondary earthquake insurance prices.

(3) Two primary vehicles exist for the effective inclusion of the fifteen LRMs into a federal earthquake insurance or reinsurance program. These are
   - o earthquake ordinances for state and local government adoption and enforcement and
   - o a system of partially risk-based insurance rates that provide financial incentives for the adoption and enforcement of earthquake ordinances.

(4) An enhanced federal program of earthquake loss-reduction can be justified by the resulting reduction of existing contingent federal liabilities, especially with respect to public and private non-profit facilities in higher risk seismic zones (2 and especially 3 and 4).

Based on project findings, we make the following recommendations:

(1) The fifteen LRMs listed in Table 1 should be incorporated into a federal earthquake insurance or reinsurance program.

(2) Small-scale maps for implementation of these LRMs throughout the nation should be developed by the insurance administrator, primarily on a scientific basis. Figure 1 could be used in the interim.

(3) FEMA should initiate an enhanced federal program designed to provide cost-effective LRMs and technical assistance and training to state and local governments. FEMA should seek the necessary resources to undertake this enhanced program.

(4) Activities identified in this report should be initiated or continued to facilitate or support the fifteen recommended LRMs.

(5) Earthquake risk methods for evaluation of LRMs and for primary earthquake insurance rating and secondary earthquake insurance pricing should be probabilistic -- i.e., evaluate all potentially damaging earthquakes. For developing equitable financial incentives for the recommended LRMs and for avoiding other administrative pitfalls, earthquake insurance rating maps should be similar to maps for LRM application, and both should be risk-based.

(6) In a primary federal earthquake insurance program, the earthquake insurance administrator should employ a combination of risk-based rates and earthquake ordinances in order to implement the recommended LRMs.

(7) In a secondary federal earthquake insurance program, possible ways of inducing LRMs include use of secondary pricing that reflects risks, agreements with state insurance regulators that risks be reflected in rates, and/or leverage from a combined primary and secondary program that requires earthquake ordinances.

(8) Continuous program monitoring, review, and improvement are essential features of any federal program initiated.

(9) Evaluation of the many issues -- in addition to loss-reduction -- related to the feasibility of a federal earthquake insurance program should be undertaken.

Table 1
Loss-Reduction Measures Recommended for a National Earthquake Insurance Program

Landuse LRMs (Applicable only in seismic zones 3 and 4)

New Development

LRM 1 Require in high liquefaction susceptible zones that geotechnical techniques be used to minimize potential ground failures for

- o new commercial, public, and residential subdivision development and
- o major modifications of commercial, public and residential subdivision development. (Exceptions of scattered construction of single-family dwellings may be considered in legal and administrative versions of this loss-reduction measure.)

LRM 2 Use zoning ordinances, subdivision ordinances, and other techniques to control new development in active fault zones, high site-amplification, landslide and liquefaction susceptible zones.

Existing Development

LRM 3 Permit reconstruction or replacement of existing development in areas identified as active fault zones, high landslide, or liquefaction susceptible zones experiencing damage of more than 50% of replacement value only if the identified risk is reduced to an acceptable level. Consider purchase of existing damaged properties in high landslide susceptible zones unless suitable measures are used to protect existing development from damage.

LRM 4 Proscribe additions to buildings in areas identified as active fault zones, high landslide or liquefaction susceptible zones unless the risks are reduced to an acceptable level, except additions to single-family dwellings up to 50% of the replacement cost, which can be made without such risk reduction.

Building Practice LRMs

New Construction

LRM 5 Eastern model codes shall be encouraged to incorporate (adopt by transcription) the latest version of the NEHRP seismic provisions. All model codes should incorporate a geotechnical component that considers local site amplification effects on strong ground motion and minimization of potential ground failure effects.

LRM 6 Building regulatory authorities should adopt and enforce model codes that have adequate seismic provisions for buildings including one- and two-family dwellings and anchorage of mobile homes. The building code should apply also to repairs of earthquake-damaged buildings to assure that losses are not repeated in subsequent earthquakes.

Table 1 (Continuation)

New Construction (Continued)

LRM 7 In seismic zones 2, 3, and 4, new essential buildings and public schools, including colleges and universities, should be designed in conformance with current model code seismic provisions.

LRM 8 In seismic zones currently designated 2 with high seismic catastrophic loss potential (designated 2*) model codes should require the detailing requirements applied to zones of high seismicity.

LRM 9 For new construction in seismic zones 3 and 4, a building "hazard rating" must be disclosed to potential buyers well before the close of escrow.

Existing Construction

LRM 10 In seismic zone 4, local jurisdictions should institute ordinances with requirements for seismic retrofit of unreinforced masonry (URM) bearing wall buildings. These buildings should be required to be upgraded to a minimum level or else demolished within a 20-year period.

LRM 11 In seismic zone 4, local jurisdictions should institute ordinances for the securing/strengthening of building parapets and external ornamentation within a 20-year period.

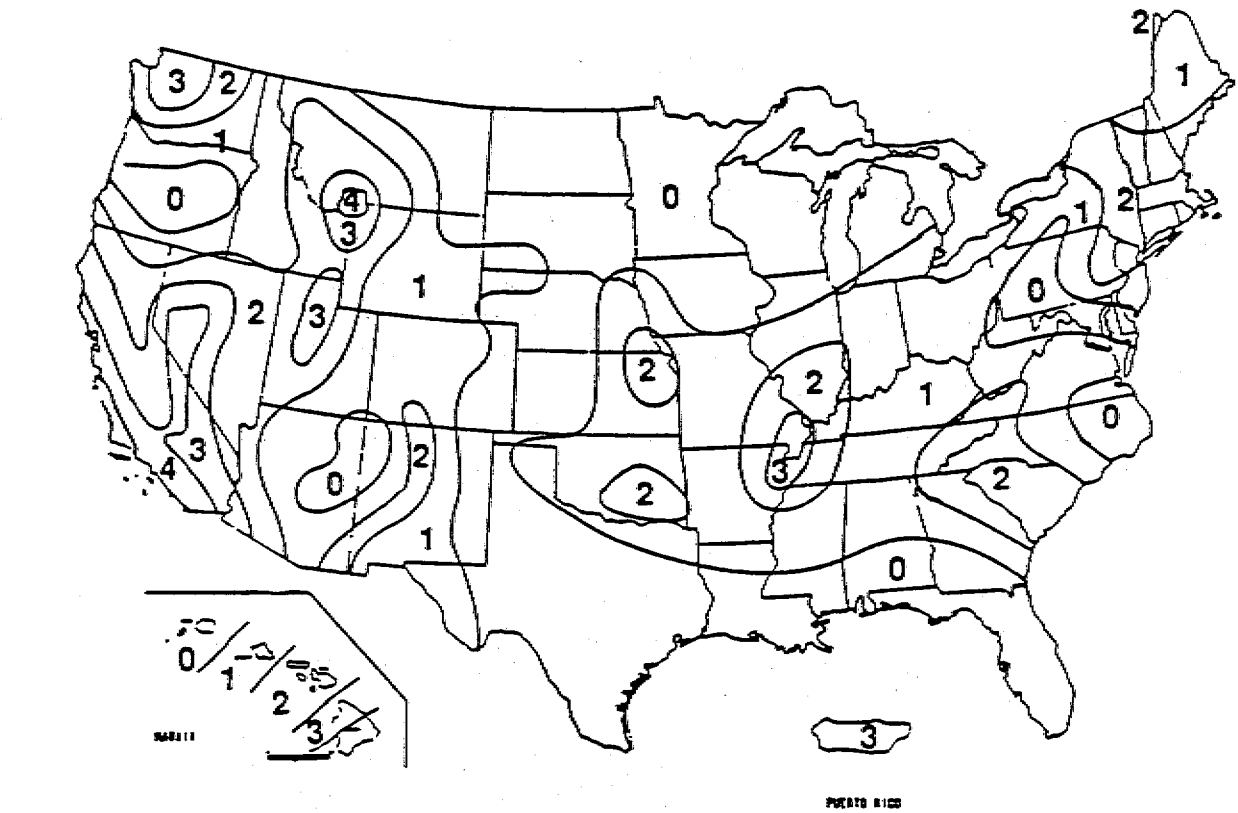
LRM 12 In seismic zone 4, potentially hazardous (other than URM) essential buildings and public schools, including colleges and universities, must be retrofitted or phased out within a 20-year period.

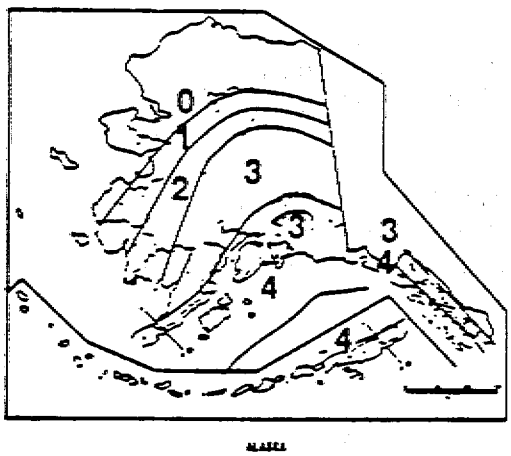
LRM 13 In seismic zones 3 and 4, inspections of buildings including one- and two-family dwellings and anchorage of mobile homes should be performed prior to significant financial commitment or property transfer and hence well before the close of escrow. A report to the potential buyer should indicate whether or not

a. the dwelling is anchored to the foundation,
b. unbraced cripple walls are present, and
c. gas water heaters (if present) are adequately braced or strapped to the framing.

LRM 14 In seismic zone 4, state law should require that gas water heaters in multi-family dwellings (new and existing) be braced or strapped to structural framing.

LRM 15 In seismic zone 4, concrete tilt-up construction which does not have adequate roof-to-wall anchors and continuity ties shall be required to be retrofitted within 10 years.





* EXPLANATION

For Adapting Figure C-1, We Have Used the Following Relationships Between Seismic Zones and Peak Horizontal Ground Accelerations:

Seismic Zone	Peak Ground Acceleration (Percentage of Gravity)	Shaking Hazard Level
0	< 0.05	Lowest
1	≥ 0.05 and < 0.1	
2	≥ 0.1 and < 0.2	
3	≥ 0.2 and <0.4	
4	≥ 0.4	Highest

Figure 1. Illustrative Seismic Zone Map for the United States
(Adapted * from "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings," FEMA Publication 18 by the Building Seismic Safety Advisory Council, 1988)

PROJECT SUMMARY

The Congress of the United States is considering the establishment of a federal insurance program designed to reduce earthquake-caused mortality, morbidity, and economic losses and to protect homeowners, businesses, and financial and public institutions from sudden and disruptive catastrophic economic losses. In anticipation of this current consideration, the Federal Emergency Management Agency (FEMA) contracted for this study (Contract No. EMW-88-C-2872) in order to have addressed some of the key issues concerning federal earthquake insurance or reinsurance. Specifically, this study has been contracted to "identify feasible alternative earthquake loss-reduction provisions and develop a strategy to FEMA for incorporation of recommended loss-reduction provisions into a national earthquake insurance program" -- if one should be created by the Congress.

Major project goals were to

- o identify, evaluate, and recommend loss-reduction measures (LRMs) that are promising for incorporation into an earthquake insurance program involving the federal government,
- o indicate appropriate earthquake risk analysis methods for assessing and applying LRMs and for setting earthquake insurance rates, and
- o describe how recommended LRMs may be incorporated into a federal earthquake insurance or reinsurance program.

Loss-reduction is considered by many to be one of the major objectives of any earthquake insurance or reinsurance program involving the federal government. Many of the other objectives of such a program, such as reducing the Federal deficit, providing stability to homeowners and financial institutions after catastrophic earthquakes, and providing affordable insurance, involve considerations beyond the scope of this report.

Diverse views are held regarding loss-reduction in a federal earthquake insurance program. Specifically, views differ on

- o the cost-effectiveness of specific earthquake loss-reduction measures and of earthquake loss-reduction measures generally,
- o the feasibility of geological mapping of local seismic hazards, seismic building reviews, and other activities to support LRMs and to provide bases for earthquake insurance rate-setting (rating),

- the proper role of the federal government, if any, in state and local landuse and building practices generally and those related to earthquake loss-reduction specifically, and

- the feasibility of incorporating cost-effective LRMs into either a primary or a secondary earthquake insurance program. (In a primary earthquake property insurance program, the insurance is provided directly to the property owner; in a secondary earthquake insurance program, insurance is provided to the insurer.)

In order to understand these positions better, we have

- held three meetings of a nationally-recognized advisory panel to identify and discuss diverse viewpoints regarding this study.

- reviewed existing information on earthquake loss-reduction activities and measures,

- identified from this information search loss-reduction measures that are technically sound,

- subjected these technically-sound loss-reduction measures to economic analysis in order to determine which activities are cost-effective and who pays for and who benefits from these activities,

- evaluated and revised selected measures at a workshop of experts and individuals from many diverse organizations throughout the United States,

As a critical part of these efforts, we have

- identified fifteen LRMs that are technically sound, cost-effective, and politically and administratively feasible for inclusion in a federal earthquake insurance program,

- identified activities needed to initiate, support or sustain these fifteen LRMs,

- determined that earthquake risk analysis methods are currently adequate for LRM assessment for community use and for earthquake insurance rating,

- clarified current contingent federal liabilities resulting from current federal disaster assistance and other federal policies and indicated how some of the activities required to initiate or to sustain recommended LRMs may justify an enhanced federal program of state and local programs and assistance to reduce these liabilities, and

- demonstrated how the fifteen LRMs can be incorporated into earthquake ordinances which, along with the encouragement of risk-based rates, can serve to make the implementation of these LRMs consistent with a federal primary or secondary earthquake insurance program, and

- provided forums permitting and encouraging the expression of a wide variety of viewpoints.

Forums for Clarifying Project Issues

Given the wide range of views on earthquake risk analysis methods, the acceptability of LRMs, the desirability of supporting activities for LRMs and for rating, and the feasibility of incorporating LRMs into a federal earthquake insurance program, no unanimity of results was possible. Instead, the project approach was to permit this wide variety of positions to be expressed, along with their rationales, so that these views could be used to modify project results or to clarify issues addressed.

For instance, a view that earthquake property loss-reduction may not be cost-effective has derived from the observation that seismic codes are life-safety based; therefore, performance of some buildings suffering total constructive loss from earthquakes is considered a success because no casualties were sustained. To address this viewpoint, we have emphasized economic criteria along with technical, administrative, and other criteria in determining the acceptability of LRMs. Past earthquake investigations have shown that buildings designed with little or no seismic resistance are much more likely to suffer higher degrees of damage -- as well as be life-threatening -- than are buildings designed to adequate current model seismic code provisions. Hence, this study concludes that a strong relationship exists between property-loss reduction and seismic safety even though model seismic codes could give more emphasis to damage control.

Risk Analysis Methods

This report contains a condensed section on earthquake risk analysis methods appropriate for a federal earthquake insurance program. Our examination of earthquake risk analysis methods has found that

- o earthquake risk analysis has advanced sufficiently over the past twenty years to provide an adequate basis for assessing LRMs and for determining earthquake insurance rates in spite of large uncertainties;

- o current techniques are adequate for the development of small-scale seismic zone maps for use by a federal earthquake insurance administrator in spite of some differences in approach;

- o seismic risk methods for inclusion in a federal earthquake insurance program should be probabilistic and should evaluate all potentially damaging earthquakes and likelihood of occurrence; otherwise, both benefits of LRMs and expected earthquake insurance losses could be either grossly underestimated or arbitrarily assigned; and

- o detailed engineering reviews of all buildings covered in a federal earthquake insurance program would be cost-prohibitive; moderate underwriting expenditures can provide a federal earthquake insurance program administrator with sufficient information for encouraging LRMs and for setting rates; and

- program monitoring of exposures and losses is essential for improving loss-reduction efforts and establishing rates along with continual review and application of pertinent research findings.

Recommended Loss-Reduction Measures

We have identified fifteen LRMs, involving both improved landuse and building practices, that are suitable for inclusion in a federal earthquake insurance program. These are summarized in Table 1.

Some of the LRMs in Table 1, namely building code requirements, apply throughout the country; however, the cost-effectiveness of implementing special building code requirements in low seismic zones has been questioned. Figure 1 is used here to illustrate different seismic zones that can be used for the application of LRM requirements in a federal earthquake insurance program. Seismic zones 0 and 1 have the least earthquake strong motion hazards. The low level of hazards in these zones implies very limited long term benefits of LRMs. Consequently, requiring LRMs in these areas in exchange for the earthquake insurance benefit may as a rule be uneconomic. Nonetheless, there are benefits to inclusion of such regions in the building code process. These benefits are derived from uncertainties inherent in the seismic zonation process which are highlighted when extremely low probability damaging earthquakes occur in regions thought to be aseismic. When this occurs seismic zone designations can be changed appropriately to reflect improved information. Purchase of earthquake insurance at very low rates in low seismic hazard zones provides economic protection against extremely low-probability events.

Figure 1 is adapted from FEMA publications (95 and 96), "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings." It is intended to illustrate how the recommended LRMs become more stringent in the higher seismic zones especially zones 3 and 4. Other seismic maps, such as those found in the 1988 Uniform Building Code or the 1982 American National Standards Institute Code are more or less consistent with Figure 1.

In all such maps, portions of California, Alaska, and possibly Montana have the highest (zone 4) seismic zone designations. Portions of Arizona, Arkansas, Guam, Hawaii, Idaho, Illinois, Kentucky, Nevada, Puerto Rico, Tennessee, Utah, the Virgin Islands, Washington and Wyoming may be high (zone 3) or higher seismic zone designations. Regions east of the Rockies with seismic zone 2 designations with high catastrophic loss potential may include portions of states possibly affected by earthquakes in New Madrid, Missouri, or Charleston,

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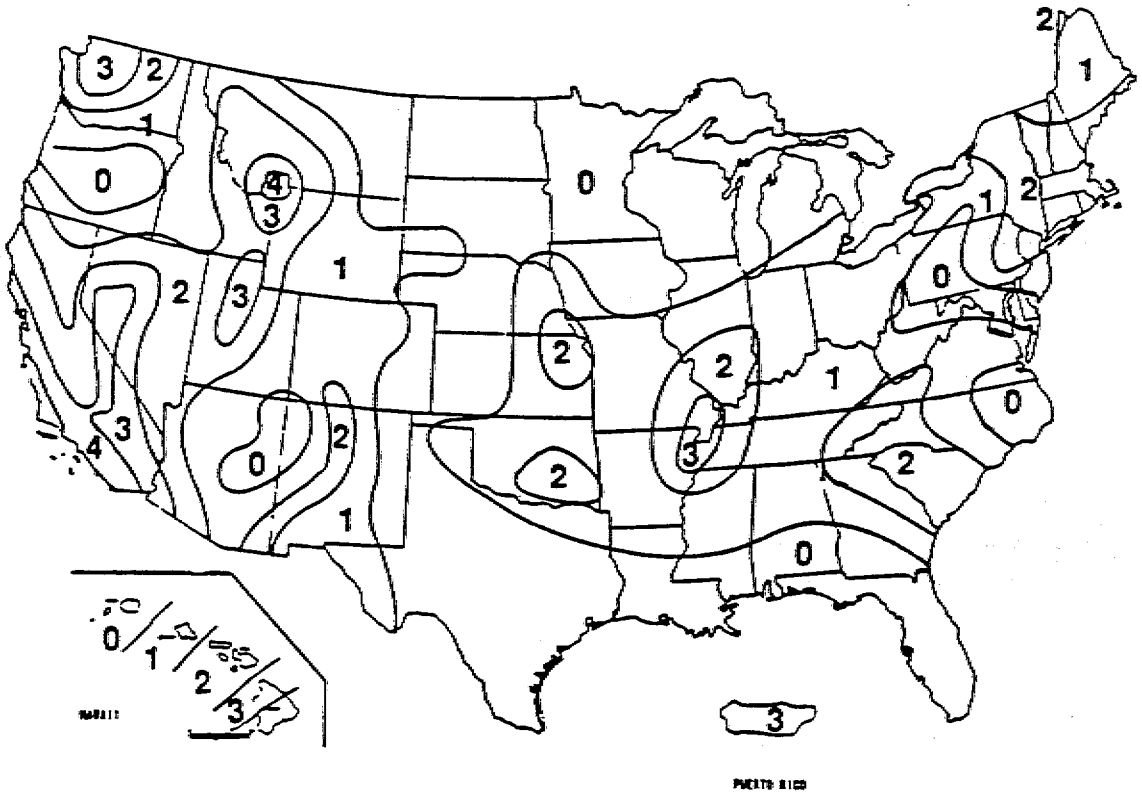

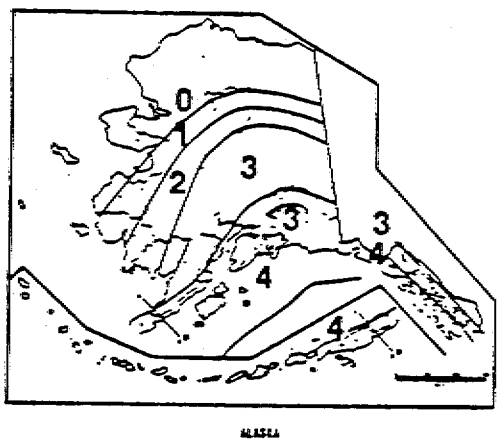

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Figure 1. Illustrative Seismic Zone Map for the United States

(Adapted * from "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings," FEMA Publication 18 by the Building Seismic Safety Advisory Council, 1988)

South Carolina, or possibly the northeastern United States. Regions west of the Rockies having seismic zone 2 designations but with high catastrophic loss potential may include portions of Alaska, Oregon, Utah and Washington.

Figure 1 could be used on an interim basis for the implementation of LRMs in a federal earthquake insurance program. One of the first steps in such a program should be the establishment of national seismic zone maps. Methods for developing these maps are currently available and being updated. These maps are technically acceptable for the LRMs recommended in this project.

Economic analysis has determined the following loss-reduction measures as being most cost-effective:

- o adoption of, compliance with, and enforcement of adequate seismic design provisions in new construction (LRMs 5, 6, 7, 8, and 9),
- o seismic retrofit of unbolted and/or poorly anchored wood-frame residences in seismic zone 4 (LRM 13), and
- o use of geotechnical techniques (supported by landuse planning) to minimize severe landslide, liquefaction, and/or subsidence hazards in seismic zone 4 (LRMs 1 and 2).

The remainder of the LRMs presented in Table 1 were determined to be adequately cost-effective and acceptable to representatives of a broad range of geographic regions and interests.

The LRMs recommended provide guidance to FEMA on which LRMs to include in a federal earthquake insurance program. Administrative discretion should be used with respect to such expressions as "50% of replacement value." Substitution of "50% of market value," for instance, may prove to be administratively easier. The LRMs recommended are expressed generally enough to represent a consensus among the professional engineers, landuse planners, economists, and state and local administrators who participated on the project. Additional specificity in terms used would require additional legal, public policy, scientific, and engineering discussion and analysis.

The emphasis in LRMs recommended lies in practices for new construction, especially with respect both to adoption, compliance, and enforcement of adequate seismic code provisions and to minimization of potential ground failure hazards during new development and major modifications of existing construction.

We have developed a list of major types of potentially hazardous construction for purposes of characterizing "potentially hazardous" construction as referenced in Table 1. This list is provided in Table 2. Other potential "hazard rating" categories include "Conforming"

Table 2

Potentially Hazardous Building Construction Classes

Identified for Public Policy Purposes

(1) Buildings with unreinforced masonry bearing walls which do not have complete or adequate load paths for seismic forces.

(2) Concrete tilt-up or reinforced masonry structures with flexible roofs. Flexible roofs include those of wood or steel deck without concrete fill. Structures having one or more of the following inadequate features:

  (a) wood ledgers used in cross-grained bending or tension,

  (b) no bolts or anchor straps for anchorage of walls to roof diaphragm,

  (c) excessive spacing or inadequate capacity of roof to wall anchors,

  (d) chord elements that are discontinuous (not supplied with continuity plates, etc.), and/or

  (e) inadequate connection of tilt-up wall panels to foundation.

(3) Non-ductile concrete frames -- concrete moment-resisting frames not conforming to the detailing provisions of the 1976 or later editions of the Uniform Building Code (UBC) and American Concrete Institute (ACI) Standard 318-77, including appendix A, (1977 edition or later) including "pre-cast" frames.

(4) Buildings with "soft" or "weak" first stories -- particularly those having story strengths less than 65 percent of the strength of the story above, as per 1988 UBC.

(5) Buildings having unreinforced or inadequately braced parapet walls or inadequately attached exterior ornamentation.

(6) Buildings with inadequately attached or rigidly attached (inadequate allowance for story drift) exterior glazing or pre-cast concrete, masonry, or stone curtain wall panels.

(7) Unreinforced masonry "infill" exterior walls.

(8) Unreinforced masonry interior partitions or "infill" walls in stairwells and elevator shafts.

(9) Buildings where no lateral force resisting system is present or can be identified either in the whole building or in a story of the building. Buildings in which the seismic lateral force resisting system is incomplete or has significant gaps that could allow portions of the structure to collapse.

(to current model seismic code provisions), "Nonconforming" (to these provisions), and "Retrofit" (to 65 percent of current model seismic design force requirements). For jurisdictions in seismic zones 3 and 4 who comply with LRMs or other model seismic codes, the distinction between "Conforming" and other hazard rating categories will be between new and existing buildings. Disclosure requirements of LRM 9 may further assist in providing disincentives for the prolonged use of potentially hazardous buildings in seismic zones 3 and 4. A major objective of a federal earthquake program is to reduce over time the seismic vulnerability of the extremely large stock of existing potentially hazardous construction, especially in higher seismic zones.

Activities Supporting Recommended LRMs

Loss-reduction measures cannot be implemented without adequate information, resources, and organizational capability. A set of activities needed to initiate, sustain, and/or support the fifteen recommended LRMs are listed in Table 3.

As with the recommended LRMs, the supporting activities are defined generally enough to achieve consensus among representatives of a broad range of interests and diverse geographic regions. Further administrative and professional effort is required to define such expressions as "minimum population" and "high liquefaction susceptibility".

The supporting elements described in Table 3, for the most part, involve a continuation of programs already underway in conjunction with both NEHRP programs and state and local practices. For instance, mapping scales required by the supporting elements are no larger than 1:24,000, and then only in higher seismic risk zones (zones 3 and 4) with significant urban development. Considerable data and maps already exist to help fulfill these requirements. As defined, the lack of full supporting elements should not delay implementation of the most significant and cost-effective LRMs in Table 1. In view of the considerable progress in NEHRP programs and the potential for future progress, the activities in Table 1 should be regarded primarily as LRMs that are cost-effective to implement -- even considering costs of supporting activities. Research that suggests additional cost-effective ways to reduce losses from earthquakes should be used to periodically evaluate and improve the LRMs included.

The Community Basis of LRM Enforcement

We recommend for adoption by appropriate state and local bodies earthquake ordinances analogous to those adopted under the national flood plain management program within the National Flood Insurance Program (NFIP).

Table 3

Activities Needed to Support Recommended LRMs

Activities Supporting Landuse LRMs
(except for L1, applicable only in seismic zones 3 and 4)

L1 For the entire United States, development of small scale maps (1:5,000,000) of ground motion, evaluated by an expert panel.

L2 For urban areas with a minimum population (e.g., 50,000) development of intermediate scale maps (1:100,000) of ground motion that include examination of local geological effects on strong ground motion (e.g., maps of relative site velocities for different spectra).

L3 Compilation and as necessary development of large scale maps (1:24,000) of Quaternary surface faulting within a 50-mile band outside the perimeter of urban areas having a minimum population. Compilation and development of intermediate scale maps (1:100,000) elsewhere in seismic zones 3 and 4.

L4 Compilation and development of large scale liquefaction and landslide high seismic susceptibility maps (1:24,000) for urban areas having a certain minimum population. Greater attention should be placed on quantitative interpretation of such expressions as "high susceptibility." Areas mapped should be large enough to accommodate short-term growth in undeveloped areas around the city.

L5 Construction of information databases and transfer mechanisms so that the foregoing maps may be readily available and understandable to local officials, realtors, developers, insurance companies, and the general public.

L6 Requirement that general plans include a seismic safety element that sets development policy for local geological hazards including high relative site response factors, fault zones, and regions of high liquefaction and/or landslide susceptibility.

L7 Development of requirements for areas identified as active fault zones, and high landslide or liquefaction susceptible zones that a geologic/geotechnical report be prepared for critical facilities, high-occupancy buildings, new subdivisions, and major modifications of high-occupancy (and/or critical) buildings, and that these be reviewed by a suitable licensed professional.

L8 Development of guidelines for preparation and review of geologic/geotechnical reports.

L9 Provision of resources for state and local programs, procedures, and staffing to effect LRMs.

Table 3 (Continuation)

Activities Supporting Building Practice LRMs

B1 Definition of "potentially hazardous buildings" as in Table 2.

B2 Definition of seismic zone 2* as those seismic zone 2 areas with high seismic potential at extended recurrence intervals and/or with high seismic loss potential.

B3 Definition of criteria and a program for seismic evaluation and retrofit of existing buildings.

B4 Provision for limitations on liability of local jurisdictions and their building official(s) when they provide and permit criteria (as in B3) for evaluation and retrofit design which is less stringent than building code requirements for new construction.

B5 Permission for voluntary seismic upgrades without mandated upgrades for non-safety related functions.

B6 Support for the development of programs and procedures and of professional state and local building staffing to effect LRMs.

B7 Support for dislocated or disadvantaged tenants during seismic retrofit programs.

B8 Continued research directed at reducing costs for seismic construction, both new and existing.

B9 Continued work to incorporate a geotechnical component into model seismic code provisions.

B10 Continued research into the development of codes that emphasize property damage control and maintenance of function over and above critical life-safety protection.

The concept of earthquake ordinances recognizes that these LRMs are implemented at state and local levels and that public agencies, as opposed to financial institutions, are the appropriate enforcers of these LRMs. The concept also recognizes that earthquake loss-reduction implementation programs require coordination among various agencies within municipalities, even though most of the currently active earthquake loss-reduction programs are handled exclusively by building safety departments. The LRMs in Table 1 are accordingly designed for adoption by state or local community-based programs. Especially in higher seismic zones, individuals, firms, municipalities, or states may, based on life-safety, economic, political, or legal reasons, decide to use higher seismic standards than those implied in Table 1. Moreover, selected insurers may provide detailed rate credits for seismic safety practices. Table 1 LRMs generally require some degree of regulation and cover a wide range of possible cases -- not merely unique motivations or circumstances.

Loss-Reduction through Enhanced Current Public Policy

We review existing earthquake loss-reduction programs at federal, state, and local levels in order to examine the framework within which project objectives can be achieved. We maintain that, in spite of the progress that has been made in these programs, further efforts at a federal level could be made to strengthen these programs and reduce existing contingent federal liabilities. A strengthened federal program could in turn provide support for the higher cost activities listed in Table 3 through reduction of these liabilities. Provision of resources for state and local programs, procedures, in particular, and staffing to effect LRMs (L9 and B6 for landuse and building practices, respectively) could be initiated based on such an enhanced federal program.

Current public policy involves no direct federal involvement in earthquake insurance and has many constraints on local adoption and enforcement of earthquake ordinances and promotion of loss-reduction activities. These include lack of adequate staffing, competition within the building construction industry to keep front-end construction costs as low as possible, and resistance to landuse planning that adjusts real estate values. One of the more significant constraints is the Federal financial contribution toward repair, restoration, and replacement of damaged facilities. Once the President has declared a disaster, Section 406 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (P.L. 100-707) commits the federal government to financing not less that 75 percent of the net eligible costs of repair, restoration, reconstruction, or replacement of public facilities and private nonprofit facilities. Expectation of the 75 percent federal cost share serves as a disincentive to the local

and state application of adequate seismic standards to construction and/or retrofit of public and selected private nonprofit buildings.

The Stafford Act does require that loss-reduction measures in the form of local codes, specifications, and standards be applied to recovery efforts financed through any disaster loan or grant under the provisions of the Act. The Act provides 50 percent financial support for hazard mitigation activities and requires natural hazard evaluation in those areas receiving assistance under the Stafford Act.

The January 5, 1990, Executive Order 12699 on Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction requires that each Federal agency responsible for the design and construction of a new Federal building shall ensure design and construction with appropriate seismic standards. Further, new buildings constructed and leased for Federal use or constructed with Federal financial assistance or regulated by a Federal agency shall appropriately use seismic safety standards. Nationally-recognized private sector standards and practices shall be used when possible or adequate local building codes. Implementation of this order should reduce earthquake losses to Federal, Federally subsidized, or Federally regulated new buildings.

While the Stafford Act and Executive Order 12699 reflect considerable progress with respect to loss-reduction efforts, the very significant contingent federal liabilities resulting from current federal policies indicate the need for increased federal controls to reduce these liabilities. Additional resources are needed to achieve the specific goal of reducing existing federal liabilities associated with potential earthquakes, even without a federal earthquake insurance program.

Federal disaster relief policy, along with other federal policies such as taxation, Small Business Administration (SBA), and Federal Deposit Insurance Corporation (FDIC) policies, supports a significant federal government interest in state and local landuse and building practices. Additional federal action to strengthen landuse and building practices for earthquake loss-reduction is warranted. Financial support for training programs and for local staffing, as was provided during the early implementation of the Clean Air Act, is an example of such needed Federal program strengthening. Part of the support for LRMs identified in Table 1 can be provided through a wide variety of federal programs specifically designed to reduce existing contingent federal liabilities.

Federal Involvement in Earthquake Insurance

One possible change in programs would involve the federal government in earthquake insurance. This would initially increase direct federal liabilities in the short term but with premium inome and loss-reduction could decrease them over the long term. In order to discuss how this may affect the implementation of loss-reduction measures, we consider

- o earthquake risk analysis methods and their application in the selection and monitoring of LRMs and in insurance rate-setting, and
- o how insurance rating influences the implementation of loss-reduction measures.

We use expected reductions in annual losses to ensure that recommended LRMs are cost-effective. However, traditional seismic loss estimation methods (expected annual loss and probable maximum loss methods, respectively) are not suitable for earthquake insurance rating purposes. Instead, new multisite methods exist which are better able to incorporate both expected annual losses and extreme fluctuation in those losses into a coherent framework for earthquake insurance rating. These methods can better deal with risk diversification and rate reduction issues. These methods also can be used to determine suitable prices in a secondary earthquake insurance context. However new these methods are with respect to earthquake, they are similar to methods used since the onset of the National Flood Insurance Program.

Protection of the public, insurance rate-reductions, and economic stability of public and private entities, with resulting benefits to individuals, would be major goals of a federal earthquake insurance involvement. Another goal -- the principal focus of this project -- would be to reduce future losses through the incorporation of loss-reduction measures into federal earthquake insurance program involvement. Without these measures, expected primary earthquake losses would increase, thus affecting adversely the safety, health, and welfare of the nation's citizens and the economic stability of the nation's public and private entities.

Two primary vehicles exist whereby implementation of LRMs such as those listed in Table 1 can be made compatible with and incorporated into a federal earthquake insurance program: (1) adoption of and enforcement of state and local earthquake ordinances and (2) a system of partially risk-based insurance rates -- rates that discourage poor seismic construction quality and encourage adoption and enforcement of adequate seismic standards. Without a system of partially risk-based rates, federal earthquake insurance involvement

would be seriously incompatible with the loss-reduction measures proposed. With partially risk-based rates, communities could be further encouraged to adopt, comply with, and enforce loss-reduction ordinances. With primary federal earthquake insurance programs, a combination of partially risk-based rates and ordinances can be strongly encouraged, as in the NFIP. With secondary federal earthquake involvement, e.g., federal reinsurance provided to primary earthquake insurers, earthquake ordinances can only indirectly be encouraged such as through secondary pricing that reflects risks of exposures to primary insurers.

Various goals can be reached with the combined encouragement of earthquake ordinances and a system of partially risk-based rates. These include short-term goals of improving the protection of the people and ensuring the nation's economic stability in the face of potential catastrophic earthquakes and the long-term goals of reducing the losses resulting from earthquakes.

Recommendations

Based on project findings, we make the following recommendations:

(1) **The fifteen LRMs listed in Table 1 should be incorporated into any Federal earthquake insurance involvement.** These LRMs are scientifically and technically valid, practical and cost-effective and have been critically reviewed by experts and representatives from a wide variety of geographic regions and interest groups. The primary loci of direct enforcement for these LRMs are state and local government authorities, not financial institutions.

(2) For implementation of these LRMs, **small-scale seismic zone maps for the nation should be developed** primarily on scientific and statistical bases. Figure 1 should be used in the interim and would be adequate for starting a federal earthquake insurance involvement incorporating LRMs. State and local jurisdictions can require additional seismic protection.

(3) **FEMA should initiate an enhanced federal program specifically designed to provide cost-effective LRMs to reduce existing contingent federal earthquake-related liabilities.** FEMA should seek the necessary legislative mandates and resources to undertake this enhanced program. This report identifies many of those liabilities and

demonstrates how they can be cost-effectively reduced to the benefit of the federal taxpayer. This recommendation supports Administrative and Congressional deficit-reducing themes discussed in Darman (1990) and GAO (1989a and b) and further supports the loss-reduction goals described in the January 5, 1990 Executive Order on "Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction." An enhanced program of this sort would provide many of the supporting elements needed for incorporation of LRMs into any federal earthquake insurance program and would further ensure that public buildings, as well as private nonprofit buildings, serve as examples of good seismic practice.

(4) Should a federal earthquake insurance program be initiated, other **supporting activities** as indicated in Table 3 **should be initiated or augmented.** In almost all instances these supporting elements are not marginally expensive. Cost considerations should not delay implementation of the fifteen LRMs. In other instances, especially B6 -- support for the development of programs and procedures and professional state and local building staffing to effect LRMs, these should be considered as part of the deficit-reducing program suggested in recommendation (3).

(5) We recommend that **probabilistic multisite risk analysis methods be used for insurance rate-setting.** Although actuarial and public policy analyses are needed to determine how rates are to be structured in a federal earthquake insurance involvement, preliminary conclusions pertinent to LRMs and rating methods were drawn. In order to account for both expected earthquake losses and potentially extreme fluctuations in those losses. Inventory of exposures should occur during application to the program. Second, we recommend **partially risk-based rates** that support and sustain the fifteen LRMs proposed. To the extent that rates reflect risks, seismic zone maps in recommendations (2) and (4) will be similar to or mirror rating maps. In contrast, to the extent that territorial or jurisdictional or other considerations enter into this public policy analysis, seismic zone maps suggested for LRMs may diverge somewhat from those for rating. To the maximum degree possible, a single mapping program should be used for both LRM application and insurance rate-setting. This offers decided administrative advantages over using widely divergent maps for LRMs and for rates.

(6) The fifteen LRMs proposed in this project can be incorporated into state and local government earthquake ordinances. **In a primary federal earthquake insurance**

program, we recommend that the administrator employ a combination of partially risk-based rates and insurance availability conditional on cost-effective LRMs being adopted and enforced and by **earthquake ordinances.** These methods are analogous to methods effectively being implemented under the NFIP. A mandatory primary program and, hence, a monopolistic program, has the potential disadvantage that an administrator may wish to cut program costs that would otherwise be incurred in a competitive market situation. These include modest costs of underwriting partially risk-based rates. As a result, rating incentives for cost-effective loss-reduction measures must be built into the objectives of such a mandated program.

(7) **In a secondary federal earthquake insurance program,** a federal insurance administrator will be faced with a difficult challenge in incorporating LRMs. **The administrator may use secondary pricing that reflects risks, agreements with state insurance regulators to ensure that risks are reflected in rates, or leverage from a combined primary and secondary federal earthquake insurance program in order to require earthquake ordinances.** We regard the incorporation of LRMs into a secondary federal earthquake insurance program as being feasible but challenging.

(8) **Program monitoring, review, and improvement are essential** features of the program envisaged here. Developments are ongoing in mapping earthquake hazards, assessing earthquake risks, and improving cost-effective risk-reduction technologies. A federal earthquake insurance program containing a loss-reduction element should systematize pertinent program information and should periodically review and evaluate this information against developments to assure continuing and improving program efficacy in loss-reduction.

(9) **Examination should be undertaken of the many issues** -- over and above loss-reduction -- **related to the feasibility of a federal earthquake insurance program.** Actuarial, economic, and public policy analyses, for instance, are needed to examine various detailed issues concerning the protection of the Federal Treasury, the provision of affordable earthquake insurance, and the reduction of post-earthquake instabilities in the financial sector of the economy. Issues of mandating insurance purchase requirements should also be examined. Further consideration should be given to how a government insurance program may and should differ from a private sector or competitive program.

1.0 INTRODUCTION AND OVERVIEW

This report constitutes the last of a series of deliverables under Federal Emergency Management Agency Contract No. EMW-88-C-2872 entitled "Loss-Reduction Provisions of a National Earthquake Insurance Program."

1.1 Contractual Background

Current concerns prompting this study are described in the contract "Statement of Work" as follows:

> The Federal Emergency Management Agency (FEMA) is considering issues related to earthquake insurance. This reflects current discussions of the need for a national earthquake insurance or reinsurance program involving the Federal Government. The Congress has been giving more emphasis to the use of insurance to deal with natural disaster losses instead of Federal disaster assistance. One of the major considerations by Congress and the Executive branch prior to approval of any Federally-assisted earthquake insurance or reinsurance program may well be whether loss-reduction is an integral part of the program's goals, objectives and procedures. . . . Any national earthquake insurance program would require a significant financial commitment by both the Federal Government and the private insurance sector. The incorporation of loss-reduction provisions would reduce potential loss exposure to both parties and provide a basis for lower insurance premiums to the policyholders. (Contract, page 9)

Because

> There are different views on how best to include loss-reduction provisions within a national earthquake insurance program, what those provisions should be, and . . . whether such provisions would be technically, economically, socially, and politically feasible. (Contract, page 9)

FEMA contracted this study in order to

> identify feasible alternative earthquake loss-reduction provisions and develop a strategy to FEMA for incorporaton of recommended loss-reduction provisions into a national earthquake insurance program. (Contract, page 9)

More specifically,

> The objective of this study is to identify, evaluate, and recommend feasible earthquake loss-reduction provisions, including safe land use and building practices, that can be incorporated into a national earthquake insurance or reinsurance program involving the Federal Government and the private insurance industry. (Contract, page 10)

The scope of the study, as described in the contract, was relatively broad:

> This study shall identify specific loss-reduction measures that can be applied to different structural classes of buildings, including almost every type of walled and roofed building. The scope should include, at a minimum, new construction, existing hazardous buildings, and critical buildings such as those used for emergency operations, police, fire, and medical services, public assembly, and schools. The study shall identify loss-reduction measures that can be taken by State and local governments, the private sector, and individual homeowners. The scientific, technical, social, economic, and politi-

cal aspects of the loss-reduction strategies and measures shall be addressed. Pertinent legal issues shall be discussed. (Contract, page 10)

Deliverables submitted prior to this report (as required by the contract) have included the following working drafts:

- "Project Workplan: Loss-Reduction Provisions of a Federal Earthquake Insurance Program" dated November 30, 1988.
- "Summary of Principal Issues: Relating to the Incorporation of Loss-Reduction Provisions into a National Earthquake Insurance Program" dated May 31, 1989.
- Report on earthquake risk assessment and portrayal methods (Contract, Task IV, page 12) entitled "Risk Analysis Methods for a Federal Earthquake Insurance Program" dated May 31, 1989.
- Report of project team efforts to "assemble and evaluate all promising strategies and measures . . . for earthquake loss-reduction" (Contract, Task III, page 11) entitled "Promising Loss-Reduction Measures In a Federal Earthquake Insurance Program," Volume I, Working Copy, July 1, 1989, and Volume II, Working Copy, July 20, 1989.
- Report of Project Workshop results entitled "Workshop: Loss-Reduction Provisions of a National Earthquake Insurance Program for the Federal Emergency Management Agency and the Federal Insurance Administration," September 30, 1989.
- Two drafts of the final report, January 15, 1990 and March 31, 1990.

This document, constituting the "Final Report" required by the contract,

proposes earthquake loss-reduction provisions along with a recommended strategy for incorporation into a national insurance or reinsurance program. . . . The supporting scientific, technical, socioeconomic, legal, and public policy data, analysis, findings, conclusions, and rationale shall be included. A general plan for continuing evaluation and modification of the loss-reduction provisions if they are incorporated into a national earthquake insurance program shall be included as an appendix. (Contract, page 20)

In an effort to provide the reader with important background information, the remainder of this section reviews the current status of federal involvement in earthquake-related loss-prevention and disaster relief (1.2), describes limitations of the scope of this study (1.3), summarizes the methods used in conducting this study (1.4), and presents an overview of the content of this report (1.5).

1.2 General Background -- The Status Quo

Consideration of the possible need for a national earthquake insurance or reinsurance program involving loss-reduction provisions acknowledges the fact that current earthquake loss-reduction programs are fragmentary. This fragmentariness in earthquake loss-

reduction programs results from a number of factors which contribute to make up current earthquake-related policy in the United States. Specifically, current fragmentariness is due to

- o local/municipal "locus of control",
- o the variety of sources of building codes,
- o the economies of scale necessary to implement loss-reduction,
- o irregular sensitivity of political bodies to earthquake-related concerns,
- o constraints on the insurance system, and
- o current disaster relief policies.

In order to understand the relationship between current efforts and a proposed national program, one must first be familiar with the status quo. Recognition of challenges within the status quo is made possible through considerable progress in research and other National Earthquake Hazard Reduction Programs (NEHRP). However, frank discussion of problems in the implementation of loss-reduction is needed to determine why fragmentariness currently exists and how modified programs, including a federal earthquake insurance program, can assist in meeting challenges for loss-reduction programs. The following discussion reviews these factors in order to establish the context in which this study was conducted.

Locus of Control

Currently, the implementation of loss-reduction measures occurs on individual and local levels. Although implementation of loss-reduction measures (as defined in section 1.3) would continue to occur at local levels, the purpose of this project requires assessing loss-reduction programs in terms of their connection to federal insurance programs. As a result, several issues related to the locus of control of loss-reduction programs require discussion. At the project workshop and elsewhere, participants emphasized the need to explain how loss-reduction measures incorporated into a federal insurance program could adequately serve national needs. Put otherwise, how would the loss-reduction program relate appropriately to Boston, Minneapolis, and Atlanta as well as to San Francisco and Anchorage?

In spite of many educational and post-disaster response advances, and other selected advances in implementing loss-reduction measures, we maintain that current earthquake loss-reduction programs are to a large degree fragmentary. This fragmentariness is reflected by

- o inadequate seismic code provisions for most jurisdictions east of the Rocky Mountains (a problem significantly being addressed in recent developments by model code organizations);

- the absence of seismic retrofit ordinances for unreinforced masonry buildings (or for other potentially hazardous buildings) except in selected California municipalities (with more ordinances likely after the October 17, 1989, Loma Prieta earthquake);
- the relative ineffectiveness of seismic elements of landuse planning programs, even in many California municipalities (Wyner and Mann, 1983); and
- the extremely large stock of potentially hazardous structures that, as a consequence of the above factors, continues to increase.

Sources of Building Codes

The fragmentary application of seismic codes to local jurisdictions is due in part to the variety of sources used to develop codes. Three key model code organizations that publish building codes are

- the International Conference of Building Officials (ICBO), which publishes the Uniform Building Code (UBC);
- the Building Officials and Code Administrators (BOCA), which publishes the BOCA National Building Code (formerly, the Basic Building Code -- BBC), and
- the Southern Building Code Congress International (SBCCI), which publishes the Standard Building Code (SBC).

One major concern in developing a national program is how federal officials should work with these model code organizations and a variety of other organizations (e.g., Structural Engineers Association of California, Building Seismic Safety Council, and the American Society of Civil Engineers) concerned with model code development.

Economies of Scale

Earthquake loss-reduction activities require economies of scale (here, especially, decreasing output costs per unit of labor or capital added) which typically include (1) large front-end costs in order to make the activities effective and (2) high degrees of specialization required to implement loss-reduction activities.

Large front-end costs are required to support such activities as construction and retrofitting to seismic standards. Unfortunately, those who must bear these costs are often hard-pressed to justify the expenditures. Fundamentally, large capital outlays may not be within the financial capabilities of many stakeholders with limited liquidity, including low-income residents, small businesses, and nonprofit organizations. Moreover, returns to be gained from high front-end costs may not be realized within short time frames. Many of these "returns" may not be investment returns, but rather "spillover" benefits to those who

occupy buildings, whether as tenants or as visitors, or to the government, which may spend less for disaster clean-up. Builders, contractors, and short-term owners may not realize the benefits of their outlays. In those cases where front-end costs prevent loss-reduction activities, dangers resulting from potentially hazardous buildings and sites are to a large degree involuntary, since stakeholders visiting, living, and working in these facilities individually have extremely limited control over siting and construction practices.

Coping with seismic design requires that design engineers, building officials, building inspectors, contractors, carpenters, masons, main workers, and steel fabricators, among others, be familiar with the technical elements of seismic code provisions. Even greater expertise is typically required for seismic rehabilitation programs.

Thus, earthquake loss-reduction typically requires investments of significant capital and technical expertise. Such funding and expertise are often not available at the local level. Successful implementation would be very expensive if individuals or firms were to undertake seismic loss-reduction programs on their own without organized social resources. These economies of scale have been proferred as one reason why seismic provisions of building codes may be required, since it would be very inefficient for consumers to make these decisions on an individual basis (See Milliman and Roberts, 1985).

Timing of Earthquake Policy Development

Another cause of current fragmentariness is explained by champions of loss-reduction programs who often speak of waiting for windows of opportunity -- typically earthquake disasters -- to promote major legislation, stronger ordinances, and improved private industry practices. (See Cheney and Whiteman, 1987; Olson et al., 1988.) With a few exceptions, economic, political, and social systems are sensitive to earthquake risk issues only on an irregular basis -- often in the unfortunate context of the disaster itself. Exceptions, for example, occur largely in states west of the Rocky Mountains, principally in California, and are expressed through building code practices, emergency preparedness drills, and other pre- and post-disaster preparations which call attention to earthquake issues, existing commercial and residential earthquake insurance purchases, and selected instances of seismic retrofit.

Private Market Insurance System Considerations

Insurance system considerations are many, but principally include financial and functional limitations on insurance companies in acting as enforcers of loss-reduction programs. Financial limitations include the inadequate total capacity of the insurance market to cover potential claims in a voluntary earthquake insurance market that lacks substantial risk diver-

sification. Specifically, the risks are not sufficiently spread geographically to limit the catastrophic loss potential to the total portfolio of an insurance company from single earthquakes. This problem of inadequate capacity can to some extent be offset by reinsurance, but the reinsurance market also has a limited capacity and raises reliability concerns because reinsurers are currently largely unregulated. Business cycles in this reinsurance market (see Cheney and Whiteman, 1987; Anderson et al., 1981) have dramatic effects on earthquake insurance availability and prices. Federal taxation and other policies exacerbate this capacity problem to the extent that insurers are less able to build up long-term reserves to meet potential earthquake losses.

Functionally, insurance companies are not necessarily in the best position to enforce earthquake loss-reduction programs. Since they are private, competitive, regulated companies subject to antitrust and other constraints, they cannot mandate earthquake insurance purchase, they operate under severe limitations on the extent to which they can share information for rate-setting and other purposes, and as private firms they have no direct concern for the spillover (e.g., public) benefits of earthquake loss-reduction programs. Within this context, decisions regarding how much to spend on underwriting and rating are largely private, and company policies in this regard may vary considerably. Reinsurers are often in an even less effective position, since they may have difficulty obtaining exposure data from primary insurers.

Disaster Relief Considerations

Causes of fragmentariness in earthquake loss-reduction efforts partly as a consequence of disaster relief programs include the following:

(1) Prior to 1988, post-disaster funding (i.e., the use of funds to pay for existing earthquake damage) was characterized by the absence of a preventive inducement.

(2) The 1988 Robert T. Stafford Disaster Relief and Emergency Assistance Act includes provisions for preventive loss-reduction. Nevertheless, for certain categories of operations (e.g., those including publicly-owned or private nonprofit buildings) there exists a strong disincentive to engage in property loss-reduction measures, because disaster relief assistance assumes a large (75 percent) payback for damage incurred should a federal declaration be made.

(3) Prior to 1990, federal buildings like state and local buildings only occasionally served as models of good seismic practice.

(4) Many segments of the population appear to misunderstand the limitations of how much federal and state governments are obligated to pay after a disaster.

These considerations suggest that, to a larger degree than is desirable, earthquake costs are "externalized," i.e., not borne by those who assume the risks. (See Atkisson and Petak, 1981 and Burby et al., 1990 for confirming evidence.) As a result, these constraints serve as disincentives to the implementation of loss-reduction activities. For smaller municipalities, owing to inadequately developed risk management, these disincentives may be not explicitly perceived as such. Nevertheless, reliance on state and federal programs for catastrophic earthquake loss-reduction, especially outside California, suggests that the disincentives, among other factors mentioned, are operable. (See Burby et al., 1990.) For purposes of background clarification, the following discussions of the 1974 Disaster Relief Act as modified in 1988 by the Robert T. Stafford Disaster Relief and Emergency Assistance Act and of Executive Order 12699 (January 5, 1990) are provided. These discussions presuppose that genuine needs are met through federal disaster assistance. This report by no means provides a comprehensive account of disaster relief programs. The implications of current practices for loss-reduction are, however, important in understanding how these practices may be improved.

Robert T. Stafford Disaster Relief and Emergency Assistance Act
(P.L. 93-288 as amended by P.L. 100-707)

Once the President has declared a disaster, Section 406 of the Stafford Act commits the federal government to financing not less than 75 percent of the net eligible cost of repair, restoration, reconstruction, or replacement of **public facilities and private nonprofit facilities.** This "net eligible cost" is based on

> the design of such facility as it existed immediately prior to the major disaster and in conformity with current applicable codes, specifications, and standards . . ..

Of particular importance is the fact that reconstruction costs are not confined to restoring the facility to its original design, but may include redesign to current applicable codes, specifications, and standards. Additionally, funding is not limited to 75 percent of allowable recovery costs.

In the context of loss-prevention programs, Section 406

- o provides for general risk reduction alternatives which include not only repair and replacement but also relocation when
  - o the facility is and will be subject to repetitive heavy damage, and
  - o the overall project is cost effective;
- o requires that currently applicable standards be used in federally assisted repairs or replacements.

In section 409, the use of "applicable codes, specifications, and standards" is required as a condition of any disaster loan or grant under the provisions of the Act. Thus, the Stafford Act requires that loss-reduction measures be undertaken for damaged structures for which federal grants or loans are made available. These standards, codes, and specifications must "apply uniformly to all similar types of facilities within the jurisdiction of the owner of the facility" (FEMA, March 1989, p. 11637).

In the context of earthquake **insurance**, the Stafford Act, as amended, also includes references. Section 311 of P.L. 100-707 requires that applicants for assistance under section 406 shall

> assure that, with respect to any property to be replaced, restored, repaired, or constructed with such assistance, such types and extent of insurance will be obtained and maintained as may be reasonably available, adequate, and necessary, to protect against future loss to such property.

Determination of "availability, adequacy and necessity" requires certification by the appropriate state insurance commissioner responsible for regulation of such insurance.

Section 404 of the Stafford Act provides federal support for **post-disaster hazard mitigation activities** related to **undamaged public and private nonprofit buildings and all commercial, industrial, and residential buildings**. Specifically, the Act states that

> the President may contribute up to 50 percent of the cost of hazard mitigation measures which the President has determined are cost-effective and which substantially reduce the risk of future damage, hardship, loss, or suffering in any area affected by a major disaster. Such measures shall be identified following the evaluation of natural hazards under section 409 and shall be subject to approval by the President. The total contributions under this section shall not exceed 10 percent of the estimated aggregate amounts of grants to be made under section 406 with respect to such major disaster.

Additionally, Section 409 (formerly part of section 406 under the 1974 Disaster Relief Act) provides for the **pre-disaster natural hazard evaluation** process in which state and local recipients of disaster loans and grants

> shall agree that the natural hazards in the areas in which the proceeds of the grants or loans are to be used shall be evaluated and appropriate action shall be taken to mitigate such hazards including safe land-use and construction practices, in accordance with standards prescribed or approved by the President after adequate consultation with the appropriate elected officials of general purpose local governments, and the State shall furnish such evidence of compliance with this section as may be required by regulation.

In theory, Section 409 may be used to enhance efforts to reduce earthquake risks after a major flood, hurricane, or other non-earthquake disaster. However, after a thorough ex-

amination of this clause in practice, Atkisson and Petak (1981) concluded that the hazard mitigation evaluation process generally has been applied to only the peril which led to the disaster for which recipients received relief and not to possible future disasters. Additionally, Brower et al. (1986) have concluded that past (pre-Stafford Act) hazard mitigation planning activities under the above clause have had little relationship to federal funding decisions. As a result, local constituencies have had little incentive to conduct natural hazard evaluations. (See Burby et al., 1990 for a broader survey.)

In review, The Stafford Act commits the federal government to significant financial liabilities following a presidentially-declared disaster due to earthquake. The act is primarily applicable to only damaged public and private nonprofit buildings. It does however promise that seismic replacement and retrofit can be required, given adequate current codes, specifications, and standards. Developments after the 1989 Loma Prieta, California, earthquake are very promising for earthquake loss-reduction activities. (See The State/Federal Hazard Mitigation Survey Team, 1990.) In addition, with state insurance regulator certification, insurance purchase can be required for repaired or replaced buildings so that a large share of the contingent federal liabilities for these buildings can be transferred to state and local governments (FEMA, March 1989, p. 11639).

Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction (Executive Order 12699 of January 5, 1990)

In support of federal efforts to develop and promulgate earthquake-resistant standards for new construction, the President issued Executive Order 12699. This order requires that

> Each Federal agency responsible for the design and construction of each new Federal building shall ensure that the building is designed and constructed in accord with appropriate seismic design and construction standards. (President, 1990)

The order specifies that local building codes affecting seismic design and construction be applied to all new construction of buildings to be "leased for federal uses or purchased or constructed with federal assistance." The order also applies in the federal regulation of the structural safety of buildings. In effect, Executive Order 12699 enhances loss-reduction efforts by exercising federal controls; however, only federally-related new construction is affected by the Order.

Limitations of Current Federal Involvement

The principal goal of current disaster policy is to ensure that economic stability be restored in regions affected by a disaster. Concerns with respect to health, life, safety, and environmental matters also exist. As a consequence, through the Robert T. Stafford Disaster Relief and Emergency Assistance Act, the federal government has accepted liability for financing a significant proportion of the cost of post-disaster recovery of public and private nonprofit facilities in presidentially-declared disaster areas. In practice, this federal liability serves as a strong financial disincentive for state and local governments to engage in pre-disaster earthquake loss-reduction projects. (See Cheney and Whiteman, 1987.)

Unfortunately, as will be discussed throughout the remainder of this report, federal controls over activities which could reduce federal liabilities are not commensurate with these potential federal liabilities. (See Burby et al., 1990.) This suggests that stronger controls are needed over the activities which could reduce these federal liabilities. At the same time, advances in science and engineering, made possible largely through national programs such as the NEHRP (and also private industry programs), have made it feasible to advance the loss-reduction measures found in this report.

As currently written, the Stafford Act mandates that communities affected by disasters employ hazard mitigation measures to reduce the risk from future disasters. These measures are not standardized; they are location-specific. Also, they are politically negotiated by state and federal officials rather than designed by damage mitigation specialists, and then they are amassed in a Hazard Mitigation Plan early in the recovery process rather than well-formulated prior to the disaster. From the standpoint of federal liability, given the Stafford Act and other existing federal policies, the federal government has a clear interest in state and local programs that affect potential earthquake losses, including those pertaining to state and local development, adoption, and implementation of seismic loss-reduction measures.

Additionally, current federal policy tools provide no means to achieve broad scale implementation of loss-prevention activities because they are mandated only for new construction of federally leased, assisted, or regulated buildings and for rebuilding in localities declared federal disaster areas by the President. Instead of being proactive and supporting the implementation of loss-reduction efforts prior to earthquake events, the current disaster policy is primarily reactive and triggered by unusual events. (See Burby et al., 1990.)

Finally, while necessary to support recovery efforts, the current policy has no provisions to address primary and secondary effects in areas other than Presidentially declared disaster areas. Thus, by itself, current policy is even insufficient to deal with the full impacts

of single disasters. The Stafford Act, therefore, is not by itself a policy that is capable of preparing the entire United States for a catastrophic earthquake.

In order to protect the United States from the effects of a catastrophic earthquake, the current disaster policy is clearly insufficient. What is needed is a mechanism which reduces both long-term and short-term losses associated with earthquakes. Such is the fundamental goal prompting this study.

Conclusions

Public policy vehicles currently available for reducing earthquake losses have not yet produced a coherent large-scale or national program of loss-reduction implementation. In addition, a pure market solution to the earthquake loss-reduction problem is not feasible, since neither earthquake insurance nor loss-control markets operate according to idealized conditions (e.g., adequate knowledge by individual consumers, absence of "adverse selection," absence of significant spillover effects). Current fragmentariness of earthquake loss-reduction programs is a problem that needs to be addressed with sensitivity to local and regional differences. Consequently, this report examines public policy vehicles available for guiding a national program. Section 5.0 includes discussions of how current public policy vehicles may be augmented given a federal role in earthquake insurance.

1.3 Project Scope

The goal of this study is to

> identify feasible alternative earthquake loss-reduction provisions and develop a strategy to FEMA for incorporation of recommended loss-reduction provisions into a national earthquake insurance program.

Throughout the conduct of this project, questions arose regarding the depth and breadth of results achievable. As specified in the project contract, the scope of the study was to include

- o different structural classes of buildings, including almost every type of walled and roofed building.
- o at a minimum, new construction, existing hazardous buildings, and critical buildings such as those used for emergency operations, police, fire, and medical services, public assembly, and schools.
- o measures that can be taken by state and local governments, the private sector, and individual homeowners.
- o The scientific, technical, social, economic, and political aspects of the loss-reduction strategies and measures . . ..
- o Pertinent legal issues . . ..
- o information and research available nationally and internationally. (Contract, page 10)

Early in the course of this project steps were taken to identify the boundaries within which this study would be conducted.

Definition of Loss-Reduction Measure

One primary issue addressed in determining project scope was how the expression "loss-reduction measure" was to be used. In the Project Workshop we defined a loss-reduction measure as requiring **a physical activity or restraint thereon that reduces expected earthquake losses.** This definition accords with the definition of "hazard mitigation" for purposes of implementing the Stafford Act. (See FEMA, March 1989, p. 11633.) The definition has both a physical and a statistical element. There must be a physical intervention in the built environment and statistical evidence that the measure reduces loss.

This definition requires that a proposed loss-reduction measure be specified in terms of a "fix" -- some action or set of activities that improve the expected seismic performance of buildings or otherwise are expected to reduce earthquake losses directly. For new buildings, this may involve selecting less hazardous sites, improving site foundations, or applying seismic codes or other techniques in order to improve the seismic performance of the building system and its nonstructural systems and contents and to reduce life-safety hazards. Avoiding especially hazardous sites in new construction falls under this definition insofar as alternative sites selected would be assessed to have lower risks. Density limitations may fall under this definition to the extent that both the expected risks are catastrophic ones and that the alternatives available to high-density developments reduce these expected catastrophic losses. For existing buildings, the fix may involve altering usage, securing equipment, instituting means to control fire following earthquake, and/or seismic retrofit of structural elements.

Many activities such as research, mapping, workshops, and the like are required to initiate, support, and/or sustain loss-reduction activities. We call these **supporting elements**. For instance, educational and training programs of various sorts may be required so that the many participants in building practices -- architects, building officials, structural engineers, developers, owners, contractors, and subcontractors -- are aware of and experienced in complying with model seismic code provisions.

We also call both loss-reduction activities and supporting activities **earthquake hazard reduction activities**. Hence, a number of earthquake hazard reduction activities exist which, although integral to the process of loss-reduction, are not themselves loss-reduction activities. For instance, research into the development of base-isolation techniques is an im-

portant earthquake hazard reduction activity that makes technically feasible the loss-reduction activity base-isolation techniques in seismic design or retrofit.

The distinction between loss-reduction measures and supporting elements is vague in some instances in which supporting elements arguably may be categorized as loss-reduction measures. For instance, development of adequate seismic provisions in model codes is included as a loss-reduction measure insofar as some local communities unfailingly adopt and enforce these model codes. In contrast, inclusion of seismic safety elements in comprehensive master plans cannot be a loss-reduction measure unless this inclusion can be shown to lead to physical actions or restraints thereon that reduce expected losses.

A broader definition of loss-reduction measure may be suitable for a more comprehensive project. For example, an activity that reduces total losses associated with earthquakes is suggested in the Selkregg et al. (1984) account of mitigation as "a management strategy to balance current actions and expenditures with potential losses from the future hazard occurrences." This broader definition would require consideration of administrative costs, insurance system costs, front-end structural and geotechnical engineering costs, marginal research, mapping, educational costs, and costs of potential instabilities to financial systems. Some of these considerations have entered into the selection of promising loss-reduction measures. Consideration of the total cost of large-scale loss-reduction programs would require many investigations beyond this project scope.

Primary and Secondary Losses

Within the limitations of this definition of loss-reduction measure, this study is principally concerned with building losses (i.e., costs for repair and/or replacement of buildings) resulting directly from strong ground motion or permanent ground displacement (not from tsunamis, seiches, or flooding generally). We do not address utility or lifeline network losses, nor do we emphasize secondary losses resulting from building damage (e.g., casualties, fire damage, business interruption, governmental downtime, unemployment, mortgage defaults, business insolvencies, and economic ripple effects generally), even though these financial concerns are worth examining in greater detail elsewhere. (See Section 5.1 and Appendix C.) Post-disaster programs are discussed in this report only to the extent that the 1988 Stafford Act contains a mitigation element for which significant funds may be available for the implementation of LRMs.

In the scope of the project as clarified in the project workplan, we examine a variety of structures, whether identified by

- o structural class, including almost every type of walled and roofed building;
- o age, including both existing hazardous buildings and new construction; and
- o function, including commercial/industrial, residential, and critical public and special private-sector nonprofit buildings (e.g., hospitals).

We do not examine a variety of infrastructure facilities, whether private or public, including

- o such electric power facilities as power plants and substations, and
- o oil, sewage, natural gas, water, or communications buried pipelines or conduits.

Among losses, we specially examine

- o direct property losses to (damage to and collapse of) buildings and contents, including those resulting from landuse policies.

These direct property losses are very important causes of deaths and injuries -- matters of the utmost importance in community safety programs. We also examine

- o other selected secondary losses (as a derivative concern) including
  - o mortgage defaults,
  - o fire following earthquakes, and
  - o business interruption costs or costs of governmental discontinuity;
- o costs of reducing losses; and
- o premium costs.

We do not directly examine

- o damage to infrastructures including utility systems and secondary losses due to their failure (including casualties),
- o secondary losses to key sectors of the economy as a consequence of direct primary losses to buildings and contents,
- o loss implications of various proposed programs to reduce economic ripple effects of catastrophic earthquakes,
- o loss implications of alternative post-disaster emergency/claims adjustment procedures, and
- o specific cost estimates of underwriting in a primary or secondary reinsurance program.

Although we certainly endorse programs that deal with tertiary needs to reduce financial instabilities and improve post-disaster emergency procedures, the goal of this project is to examine loss-reduction measures that reduce primary earthquake losses, and to that extent

secondary earthquake losses. We have defined the expression "loss-reduction measure" with this limitation in mind, but we encourage other studies to examine proposals to reduce economic ripple effects of earthquakes and other large-scale disasters and to improve emergency management procedures. In section 5.0, we explain how the objective of ensuring financial stability on a nationwide basis after a large catastrophic earthquake provides a major reason why incorporation of loss-reduction provisions into a federal earthquake insurance program is considered in this project.

The entire issue of rating in an earthquake insurance program involving the federal government requires many investigations beyond this study. This study confines itself to an examination of risk methods suitable for earthquake insurance rating and to key discussions of the role of rates as either powerful incentives or disincentives for undertaking loss-reduction measures. Although the extremes of (a) very detailed underwriting or (b) virtually no underwriting are not supported in this report, no precise underwriting costs have been developed.

Financial Surpluses in an Insurance Program

Another topic not within the project scope pertains to possible financial reserve developments in any federal earthquake insurance involvement. This exclusion leads to the following limitations:

- o our inability to determine whether or not earthquake insurance purchase should be mandatory,
- o limitations on our ability to examine possible consequences of mandatory earthquake insurance purchase such as who pays for and who benefits from this monopolistic setting,
- o our inability to estimate with any degree of accuracy total costs associated with any of the possible types of federal insurance involvement, and
- o our inability to determine if funds to support loss-reduction program administration would be derived from the insured or the general taxpayer or both.

With respect to the last consideration, we do maintain that some of the costs of incorporating loss-reduction measures may be borne by a taxpayer-based program specifically designed in a cost-effective manner to reduce existing contingent taxpayer liabilities.

Feasibility of Federal Insurance

Although this project addresses generally how loss-reduction provisions may be incorporated into a federal earthquake insurance program, we do not address the much broader

topic of whether or not a federal earthquake insurance program is feasible. This much broader topic may include many public policy, legal, economic, actuarial, and risk analyses that include discussions of many of the topics excluded from this project, such as

- o loss and cost implications of various proposed programs to reduce economic ripple effects of catastrophic earthquakes,
- o advantages and disadvantages of other alternative federal earthquake program changes such as strengthened federal legislation to control existing contingent taxpayer liabilities associated with earthquakes,
- o economic and political implications of the role of government as an "insurer" or "reinsurer," a role more traditionally assigned to business,
- o public policy and socioeconomic considerations affecting how rates should be estimated in a federal program,
- o legal implications of various specific proposals for federal earthquake insurance involvements, and
- o the extent to which a federal earthquake insurance involvement combined with disaster assistance would solve all problems associated with very large potential earthquake losses.

Types of Federal Earthquake Insurance Involvement

To a limited extent, the project scope includes discussion of various types of federal earthquake insurance involvement, including

(1) revision of the status quo (including the 1988 Stafford Disaster Relief and Emergency Assistance Act),

(2) the federal government as primary insurer,

(3) the federal government as reinsurer, and

(4) some combination of (2) and (3).

In considering these involvements this report does not include a detailed account of all possible stakeholder liabilities under all four types of federal earthquake insurance. Additionally, in examining these four involvements, we do not examine claims adjustment and other post-disaster emergency procedures and other key features of disaster relief policy. Nor does this report thoroughly examine all earthquake-related policies or the Stafford Act, which from the limited standpoint here reflects progress over previous disaster relief policy (which had less of a loss-reduction component).

Since current contingent federal and state liabilities are a direct consequence of existing disaster relief provisions and tax statutes, the status quo must be regarded as a set of cir-

cumstances that contains various potential strengths, liabilities, problems, and public policy implications. The broader decision procedures used in this study treat the status quo as one of many alternatives to be considered. Through consideration of the public policy implications of the status quo, justification can be found for strengthening the mitigation component of federal programs and thus taking advantage of the knowledge gained through NEHRP (National Earthquake Hazard Reduction Program) programs.

The strengths of NEHRP programs are not the topic under current discussion. Nevertheless, this report recognizes that advances in the many disciplines supporting earthquake loss-reduction efforts have been significant in the decades since the 1964 Good Friday Alaskan earthquake and the 1971 San Fernando Valley earthquake. It is presupposed in this report that federal disaster relief programs provide needed post-disaster assistance to state and local governments, to small businesses, to private nonprofit organizations, and to individuals with limited liquidity. Still, consideration of both earthquake loss-reduction and of earthquake insurance suggests possible significant improvements in current federal programs -- improvements that build on past efforts.

1.4 Brief Summary of Methods and Procedures

In order to achieve the goals of this project, a significant effort was directed toward identifying, defining, and assessing feasible loss-reduction provisions and developing strategies for incorporation of recommended loss-reduction provisions into a national earthquake insurance program.

- A project team was assembled. Team members made very thorough searches of planning, scientific, and engineering information, in order to identify and exhaustively evaluate earthquake hazard reduction activities which could be useful in loss-reduction programs. Steps were taken to ensure that these hazard reduction activities apply to diverse regions of the country, to diverse building usages, and to diverse landuse and building practices. This search produced a collection of 96 earthquake hazard reduction activities for consideration.

  The project team used expert judgment to select, synthesize, and restate hazard reduction activities as a smaller number of more technically credible loss-reduction measures (LRMs) to be subjected to more rigorous analysis. During the course of this process LRMs naturally fell into two groupings -- Landuse Measures and Building Practices. Consistent terminology was applied throughout the two groupings, and supporting elements were restated so that practices needed to implement the LRMs could be encouraged. (See Section 4.2.)

  The project team developed an interactive socioeconomic risk-and-decision model in order to evaluate the technically promising loss-reduction measures on two grounds -- economic efficiency and economic allocation. The analysis provided important information regarding the cost-effectiveness of candidate LRMs and estimated costs and benefits to various key stakeholders (e.g., the general taxpayer, lending institutions, owners,

tenants, insurers). This information was then compiled for presentation at a project workshop.

Concurrently,

- We held three meetings of an **Advisory Panel** whose nationally recognized members represent a broad range of professions, interests, and geographic regions. (See Appendix A for biographical sketches.) The main purpose of the Advisory Panel was "to ensure that the broad range of scientific, engineering, planning, insurance industry, and public policy information and viewpoints [were] considered in the study." (Contract, p. 11) We did not ask the Advisory Panel to concur with project findings, and this report reflects only their inputs, not necessarily their viewpoints.

  We held the **first meeting** of this panel on January 25, 1989. At this meeting the panel reviewed the project workplan and, in an open discussion, considered the scope of the study and the evaluation criteria for identifying promising loss-reduction measures. Throughout the project, some participants wished to restrict the project scope to consideration only of residential construction and to obviate all discussion of the relationship between rates and LRMs.

  At the **second Advisory Panel meeting**, held on June 8, 1989, panel members were introduced to preliminary results of project team efforts to identify loss-reduction measures, a review of the methods being used, and supporting documentation. The panel reviewed, in particular, the Issues and the Risk Analysis working reports.

- On August 15 and 16, 1989, we held a **Project Workshop** composed of recognized experts and interested and affected parties representing a very broad spectrum of interests, professions, and geographical regions in order to review and comment on previous project findings. In particular, those findings pertain to proposed loss-reduction provisions and their strategy for implementation in a national earthquake insurance program. The workshop was to provide for further consideration of the views of diverse interest groups and help assure that the proposed measures are professionally supportable, and acceptable to communities, the insurance industry and policyholders. The workshop was structured to encourage the introduction of new information and innovative ideas.

- The Project team synthesized, in a **draft** of this **report**, results of previous project steps. Specifically, these procedures resulted in the identification of a number of loss-reduction measures (LRMs) considered to be promising in some sort of federal program. These include LRMs involving both landuse planning and building activities, covering all geographic regions including both existing buildings and new developments, and covering residential, commercial/industrial, and institutional buildings. Also included are supporting elements, i.e., activities or measures required to initiate, support, or sustain promising LRMs. (Section 4.0) These promising LRMs are here regarded as applicable in defining potential "earthquake ordinances" (earthquake-resistant standards) for various portions of the country. In section 5.0, we examine how earthquake ordinances fit into various types of potential federal earthquake insurance involvements.

- On January 18, 1990, a **third meeting of the Advisory Panel** was held to review and discuss the content of the draft report in order to ensure that the results of the study would fully meet the contractual requirements in the project charge. At this meeting, lively exchanges took place regarding

- the possible role of earthquake insurance rate incentives for either encouraging or discouraging LRMs,
- how risk-based rates reflecting landuse LRMs should be encouraged along with risk-based rates reflecting building practice LRMs,
- how a federal insurance program differs significantly from a private insurance program,
- how direct federal rate-setting in a secondary federal insurance program may usurp rights of state insurance regulators,
- the extent of a federal interest in state and local practices,
- whether or not the draft report unintentionally exaggerates weaknesses in current federal programs at the expense of their strengths, and
- whether or not the fifteen recommended LRMs were acceptable to scientists, engineers, economists, and state and local officials over a wide geographic region.

- On March 31, 1990, a revised **final draft** was submitted for review by the Advisory Panel, the project officer, and, through the project liaison, to federal officials on the interagency task force on earthquake insurance.

1.5 Summary of Content

This report

- examines risk methods for both assessment of LRMs and for earthquake insurance rating,

- analyzes earthquake hazard reduction activities on technical, administrative, social, economic, political, and legal grounds as a means to develop recommended loss-reduction measures, and

- for the fifteen recommended LRMs, identifies general strategies whereby these can be incorporated into a national earthquake insurance program.

Section 2 addresses the topic of risk analysis as it applies to earthquake-related (seismic) concerns. Rather than simply summarizing currently available risk analysis methods and their functions, strengths, and limitations, this discussion stresses the suitability and application of various risk methods for the assessment of the cost-effectiveness of loss-reduction measures and for insurance rating. Specifically,

2.1 outlines the basic steps in risk analysis, describes the types of seismic risk analysis methods available, addresses questions of uncertainty in seismic risk analysis in insurance contexts, and recommends applications appropriate to implementation of loss-reduction measures and earthquake insurance.

2.2 examines the application of risk analysis methods to evaluating and setting earthquake insurance rates under different contexts of federal involvement.

2.3 addresses earthquake hazards mapping activities essential to incorporating loss-reduction provisions in a federal earthquake insurance program.

Section 3 identifies earthquake hazard reduction activities and analyzes these on technical, administrative, and economic grounds.

3.1 summarizes the process used to identify, define, and assess possible loss-reduction provisions appropriate for inclusion in a national program for insurance or reinsurance.

3.2 reviews the results of thorough efforts to identify earthquake hazard reduction activities which would satisfy the definition of loss-reduction measure and which, on technical and administrative grounds, also appear to be worth further examination as possible recommended LRMs.

3.3 reviews the process of socioeconomic analysis of these possibly acceptable LRMs, details the methods used to estimate costs and loss reductions, and reports the findings of socioeconomic analyses conducted to determine whether or not the technically feasible LRMs could be considered cost-effective.

Section 4 reviews the procedures used to ensure that recommended loss-reduction provisions would be considered acceptable on political and legal as well as social, economic, technical and administrative grounds and identifies loss-reduction provisions which potentially could be incorporated into a national insurance or reinsurance program.

4.1 describes the stakeholder analysis conducted in conjunction with this study.

4.2 presents the results of this analysis.

4.3 describes the Project Workshop at which cost-effective LRMs were discussed, revised, and refined to be acceptable to a wide range of knowledgable and interested parties.

4.4 presents a set of loss-reduction measures (LRMs) and necessary supporting activities that can be used in developing "earthquake ordinances" or earthquake-resistant standards for communities throughout the country.

Section 5 considers how loss-reduction provisions may be incorporated into three general types of federal earthquake insurance constructs.

5.1 presents an overview of the possible roles the federal government could play in the provision of earthquake insurance and discusses how the incorporation of LRMs fits generally into federal earthquake insurance and disaster relief objectives.

5.2 reexamines current earthquake-related policies and contingent federal liabilities, reemphasizes the fragmentariness of current national earthquake-loss-reduction policies, suggests means through which existing programs to effect many of the supporting elements of an LRM program, and recommends enhancement of those programs specifically to reduce in a cost-effective manner existing contingent federal liabilities.

5.3 considers how the rate structure of an earthquake insurance program will affect the implementation of such loss-reduction provisions as are recommended in this report.

5.4 considers as one major change in public policy the federal government as a primary earthquake insurer and how LRMs may be incorporated into such a primary federal earthquake insurance program.

5.5 addresses how LRMs can be incorporated into a secondary federal earthquake insurance programs.